New CCIR Report on SETI

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Since 1978, the reports and recommendations of the Comité Consultatif International des Radiocommunications (CCIR) have included a document describing SETI (the Search for Extraterrestrial Intelligence) in the context of radio frequency management. A new report to replace the old one has been adopted by a CCIR study group; both reports were written at JPL. Following introductory and background material, the text of the new report is given.

I. Introduction

The Comité Consultatif International des Radiocommunications, or CCIR (International Radio Consultative Committee), provides the technical rationale for the international treaty which governs the use of the radio frequency spectrum. Reports and recommendations of the CCIR are published at four-year intervals; Volume II, *Space Research and Radioastronomy* [1], has included a report dealing with SETI (the Search for Extraterrestrial Intelligence) since 1978. CCIR, a part of the International Telecommunication Union, includes a number of study groups. Study Group 2 deals with space research and radioastronomy and is responsible for the content of Volume II of the reports and recommendations.

For the November 1987 meeting of the CCIR Study Group 2, the United States proposed that a new report on SETI, written at JPL, be adopted as a replacement for the now obsolete 1978 document. The new report was adopted, and the text is given in Appendix A.

II. Background

The treaty mentioned above finds expression in the *Radio Regulations* [2], published by the International Telecommunication Union. With the exception of a few advisory statements that mention that SETI searches are being conducted, the *Radio Regulations* focus on the needs of other radio services for transmission bands and protection from interference. Considering the intense competition by government and commercial radio services for spectrum space in the microwave region of greatest interest to SETI, it is not surprising that there is no explicit regulatory protection for SETI searches.

SETI researchers would like to be able to listen at any frequency of interest without encountering man-made interference. Any man-made radio emission, authorized or not, intentional or not, is a potential impediment to a successful SETI search. Particularly because the range of interesting SETI frequencies is so very wide, regulatory protection from interference is simply not a practical expectation. Indeed,

listen-only allocations for radio astronomy and passive earth sensing activities are possible only because the needed frequency ranges are relatively narrow. Transmissions in these bands are prohibited, and the allocations take into account the requirement to detect signals in known frequency ranges that are dictated by physical processes. This is quite different from the SETI case where the needed frequencies are not known.

Because regulatory protection cannot be obtained, another approach must be taken to achieve at least some cooperation that could assist SETI. The approach taken by the United States has been to have a report in the CCIR literature that explains the SETI needs. CCIR reports are formally adopted by the International Telecommunication Union and represent an international technical agreement with the report contents.

The new CCIR SETI report, like its predecessor, was written at JPL, and survived an intensive review by technical peers, NASA, and a broad cross section of frequency management experts within the United States before being submitted by the Department of State to CCIR in Geneva.

III. Text of the New Report

Appendix A presents the verbatim text of the new report. Because the intended audience is familiar with CCIR documents, complete citations of referenced reports or other CCIR documents are not needed or given. For a more general audience, it is perhaps helpful to provide the following citations.

Reports 719 and 721, mentioned in Section 3 of Appendix A, may be found in the International Radio Consultative Committee's *Recommendations and Reports of the CCIR, 1986, Volume V: Propagation in Non-Ionized Media* (Geneva: International Telecommunication Union, 1986). Report 719-2 is entitled "Attenuation by Atmospheric Gases"; Report 721-1 is called "Attenuation by Hydrometeors, in Particular Precipitation, and Other Atmospheric Particles."

Document 2/60, mentioned in Section 4.1 of Appendix A, is a Draft New Report, *Method of Calculating Attenuation, Noise Temperature, and Telecommunication Link Performance for the Selection of Preferred Frequency Bands*. This report, written at JPL and submitted by the United States to the CCIR, was approved by Study Group 2 during its interim meeting in Geneva from November 16 to December 4, 1987. Report 700, mentioned in Section 7 of Appendix A, may be found in the International Radio Consultative Committee's *Recommendations and Reports of the CCIR* (Geneva, International Telecommunication Union, 1986).

The subtitle of the report shown in Appendix A includes a reference to Question 17/2. CCIR work is guided by formally adopted statements that describe the considerations which lead to a decided set of needed studies. These statements are called questions. The current version of Question 17/2 was adopted in 1982, and the text may be found in Appendix B.

The SETI report shown in Appendix A is considered a draft because, although adopted by Study Group 2 at its interim meeting in Geneva last year, it has not yet been adopted by the entire CCIR meeting in Plenary Assembly. That will occur in 1989 or 1990. One must be patient in CCIR work.

Acknowledgment

References

[1] International Radio Consultative Committee, *Recommendations and Reports of the CCIR, 1986, Volume II: Space Research and Radioastronomy*, Geneva: International Telecommunication Union, 1986.

[2] *Radio Regulations*, Geneva: International Telecommunication Union, 1985.

Appendix A

RADIOCOMMUNICATION ASPECTS OF SYSTEMS
TO SEARCH FOR EXTRA-TERRESTRIAL INTELLIGENCE (SETI)

(Question 17/2)

1. Introduction

Many scientists believe that life may be common in our galaxy and that it could have developed into advanced forms that possess a telecommunication capability similar or superior to ours. We do not know the frequencies, modulations, polarizations and locations of transmitting stations used by extra-terrestrial civilizations, if they exist. To discover signals from these stations, it is necessary to make an extensive search of the radio frequency spectrum, in all directions from Earth. The conduct of such a systematic search with great sensitivity has become feasible in recent years.

The possibility of receiving radio signals from extra-terrestrial intelligent life was first pointed out in 1959 [Cocconi and Morrison, 1959]. The first search in the microwave region was carried out in 1960 [Drake, 1960]. Since then at least 47 searches have been conducted by 8 countries, utilizing 24 observatories [Tarter, 1985]. These efforts have not detected evidence of signals from extra-terrestrial beings. The searches, however, covered only a tiny fraction of the frequencies, modulation schemes, and directions that are considered reasonable choices from the point of view of a comprehensive search, and at sensitivities that may not have been adequate.

Additional comprehensive searches are being planned and implemented.

2. Search considerations

Assuming that signals from extra-terrestrial beings are reaching the Earth, our ability to detect them depends upon

a.   the flux density of the signals arriving at Earth,

b.   the collecting area of our antenna, and its illumination efficiency,

c.   the sensitivity of our receiver,

d.   our ability to point our antenna in the correct direction,

e.   and our ability to distinguish the received signal from natural noise and from the man made electromagnetic environment.

The flux density of an extra-terrestrial signal depends on the transmitted e.i.r.p. and the characteristics of the path of propagation.

3.   Signal power flux density [1]

The flux density of the signal to be detected is unknown.   Because of the very great distances that are necessarily involved, the flux density may be very low, and detection would therefore be limited by the sensitivity of the receiving system.

For a receiving system on the surface of the Earth, the attenuation of the atmosphere reduces the strength of the unknown signal. The attenuation is a function of frequency and weather condition [Reports 719, 721].

For a receiving system located outside the atmosphere of the Earth, for example, on the Moon, the attenuation of the atmosphere is avoided and the possibility of signal detection is correspondingly improved.

Fig. 1 presents curves of signal power flux density as a function of e.i.r.p. for several assumed distances, not including the attenuation of the atmosphere.

4.   Receiving system sensitivity

For a given antenna gain, the sensitivity of the receiving system to be used for SETI search is determined by its system noise temperature, the resolution bandwidth chosen for the search, and by the integration time.

4.1   System noise temperature

System noise temperature is determined by the characteristics of the equipment plus the sky noise temperature seen by the receiving antenna. For receiving equipment with a very low noise temperature, e.g., less than 30 K, sky noise can be a fundamental limitation to system sensitivity at some frequencies.

For a receiving system outside the atmosphere of the Earth, the sky noise is determined by the cosmic background noise (3 K) plus radio noise emissions from our galaxy. The total sky noise temperature is less than 7 K between approximately 1 and 100 GHz, and this range is called the free-space microwave window.

Sky noise as seen from the surface of the Earth during clear weather, with an atmospheric water vapor density of 7.5 gm/m^3, 90 deg elevation angle, is less than 7 K between approximately 1 and 15 GHz [Document 2/60]. In the 15 to 100 GHz range, the sky noise contributed by the atmosphere rises appreciably, primarily due to H_2O and O_2, thereby reducing the probability of detecting extra-terrestrial signals that may be present.

As limited by sky noise temperature and its effect on receiver sensitivity, the frequency range over which maximum sensitivity may be realized is much reduced for a station located on the surface of the Earth, as compared to one located outside the atmosphere.

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[1] In the context of this report, the term "power flux density" refers to power per unit area. This meaning is consistent with definitions and usage of the International Telecommunication Union. Some readers may use the term in a different way.

4.2 Signal integration time

By integrating the signal-plus-noise power over a period of time, the signal to noise ratio for a continuously present signal may be improved by approximately (bandwidth x integration time)$^{0.5}$. Integration is one of several effective modes for signal detection. The time of integration is limited by two factors: signal frequency stability, and the observation time available on desired antenna systems.

4.2.1 Frequency stability

The frequency of the arriving signal will include a Doppler shift that depends on the relative velocity between the transmitter (at the time of transmission) and the receiver. This shift may change with time as a result of relative acceleration of the transmitter and receiver. The signal to noise ratio improvement that results from integration depends upon the ability to track the Doppler shifted signal. The improvement in signal to noise ratio resulting from non-coherent integration may be reduced as a result of imperfect signal frequency tracking.

4.2.2 Available search time

The total time it will take to search the volume of space in which there might be extra-terrestrial intelligent life depends on the signal integration time per channel, the number of antenna pointing directions, and the range of frequencies to be included. If the time available for use of particular search antennas is limited, the integration time for each channel and for each pointing direction is correspondingly limited. Under these circumstances the search sensitivity is constrained by the time available for the planned search.

4.3 Minimum detectable signal power

For a signal that remains within the detection bandwidth during the integration time, the minimum detectable signal power of the search receiver, assuming a signal-to-noise ratio of 1, is given by [NASA 1973]:

$$P_{min} = 10 \cdot LOG \left[kTB \cdot \frac{1 + (1 + B \cdot tau)^{0.5}}{B \cdot tau} \right] \quad dBW$$

where

k = Boltzmann's constant

T = Temperature (K)

B = detection bandwidth (Hz)

tau = integration time (sec)

Fig. 2 shows P_{min} as a function of integration time for several bandwidths. Points A and B in the Figure identify P_{min} for two candidate search receivers with the characteristics listed in the legend.

Fig. 3 illustrates the relationship between the received power flux density for the conditions assumed in Figure 1, and the search sensitivity of two candidate receiving systems. The dashed horizontal line represents the sensitivity of a system using a 34m diameter antenna with 50% efficiency, 30 K noise temperature, 10 Hz bandwidth, and 2 sec integration time. The solid line represents the sensitivity of a system using a 300m diameter antenna with 50% efficiency, 30 K noise temperature, 1 Hz bandwidth, and 1000 sec integration time. Combinations of e.i.r.p and distance that result in detectable flux densities are those that lie above the respective sensitivity lines for the hypothetical systems.

When detection bandwidth is not limited by signal frequency drift, the most sensitive receiver is obtained by use of a detection bandwidth which matches the spectral width of the received signal. The problem is that this bandwidth is not known in advance. An associated problem is that, for a single receiver, reducing the detection bandwidth correspondingly increases the time needed to search a particular frequency range, unless a large number of narrow detection channels can be used simultaneously. For example, to search the range from 1 to 2 GHz with a single channel receiver having a bandwidth of 1 Hz and an integration time of 10 sec would require 317 years. It is for this reason that comprehensive searches utilize receivers that are able to simultaneously examine millions of spectral channels, each having a narrow detection bandwidth.

5.   Antenna pointing direction

Antennas with high gain (large collecting area) are desirable in order to increase search sensitivity and correspondingly enhance the probability of detection. The associated difficulty is that an increase in gain results in a decrease in beamwidth, with a corresponding increase in the number of pointing directions needed to search a given fraction of the sky. For a given integration time, an increase in pointing directions results in an increase in total search time.

Antenna pointing strategies and the selection of integration time and other system parameters are important elements of the design of a SETI search.

6.   Signal identification and interference rejection

A principal problem facing the discovery of extra-terrestrial signals from another intelligence is the successful determination that the detected signal is not the result of noise, natural or man-made.

The probability that the amplitude of random noise will exceed a given value is well understood. A noise peak that exceeds a given threshold value will be detected and is called a false alarm. The threshold value determines the false alarm rate, and this rate may be calculated for the case of Gaussian white noise. Raising the threshold in order to reduce the false alarm rate reduces the receiver sensitivity.

With the exception of natural astrophysical emissions or an extra-terrestrial signal, signals received by a search station will be man-made. It is therefore necessary that the search station have the ability to classify these signals and reject them as candidates for possible further observation and analysis. The rejection may be based on a-priori knowledge of signals in the environment of the search station, or be based on measurements made by the station. The success of excluding these interfering signals from the data base used for further detailed analysis is a major component in the feasibility of a successful search.

The increasing use of the radio frequency spectrum as time passes suggests that SETI searches should be conducted as soon as possible in order to minimize the problem of radio frequency interference. It should be noted that, from the point of view of SETI, all man-made radio emissions, authorized or not, represent potential radio frequency interference.

The rapidly growing use of the geostationary satellite orbit will increasingly preclude the possibility of searching a zone of the sky above the equator of the Earth within the frequency ranges used by satellite transmitters. The size of the zone is determined by the number of geostationary satellites and their e.i.r.p.

7. Candidate bands to be searched

Keeping in mind that the frequency and other characteristics of extra-terrestrial signals are unknown, it is nevertheless necessary to decide the bands of frequencies with which a search should begin. For search stations on the surface of the Earth, maximum sensitivity is limited by the noise temperature and attenuation of the atmosphere, as described earlier. Additionally, a number of particular bands have been postulated as likely candidates for search on the basis of physical principles.

A detailed discussion of the rationale for selecting particular frequencies as candidates for early or intensive search is beyond the scope of this report. Report 700-1, Geneva 1986, presents some of the rationale for certain frequencies. A common aspect of proposals for particular search frequencies is that they lie near spectral lines of natural radiation, e.g., atomic hydrogen (1420 MHz), the hydroxyl radical (1612, 1665, 1667, and 1720 MHz), formaldehyde (4830 MHz), and the ground state spectral line of the lightest artificial atom, positronium (203.385 GHz). The assumption is that extra-terrestrial beings may elect to transmit on frequencies near to these emission lines, or perhaps some multiple of them, with the idea that other civilizations would be aware and would listen accordingly.

Several bands allocated to the radioastronomy service are protected from man-made emissions, and there are similar bands for passive sensing. Because of their protection from interference, these bands are also candidates for use in connection with SETI searches.

There are many points of view concerning the frequencies that may be used for extra-terrestrial communication. It must be remembered that we have no reliable a-priori knowledge about the character or existence of signals we are attempting to receive. It is for this reason that comprehensive searches over wide frequency ranges and in all directions from Earth are proposed.

8. Conclusion

The possibility of detecting radio signals from other civilizations in our galaxy, if they exist, is strongly dependent upon a quiet radio environment at sites where searches for these signals are conducted. Although it is true that modern technology will allow some discrimination against man-made signals, it is also true that the use of the radio spectrum for a wide variety of telecommunication services and functions is rapidly increasing the need for such discrimination. As time passes, the probability of successful detection is correspondingly reduced.

It is therefore important that the requirements for the search for extra-terrestrial signals be kept in mind, and that cooperation be encouraged to the maximum degree possible to protect search sites from interference.

REFERENCES

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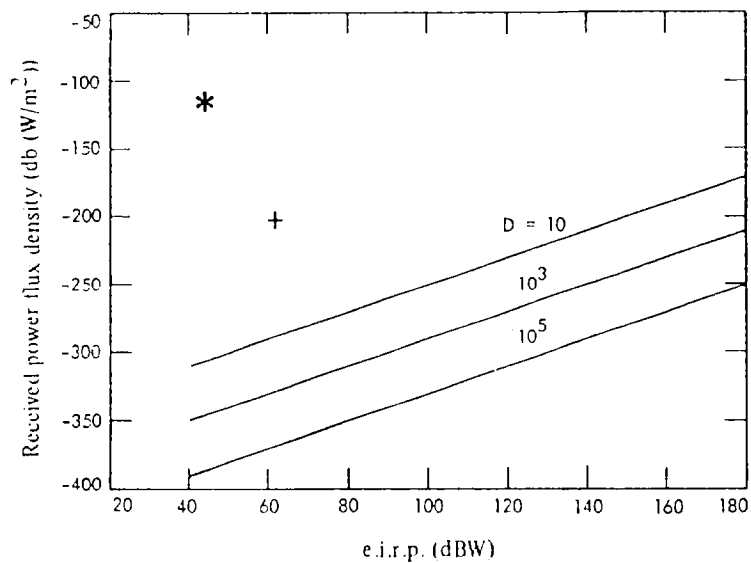
Figure 1 – *Received power flux density versus e.i.r.p.*

D: Distance, light years. (1 light year = 9.46×10^{15} m)
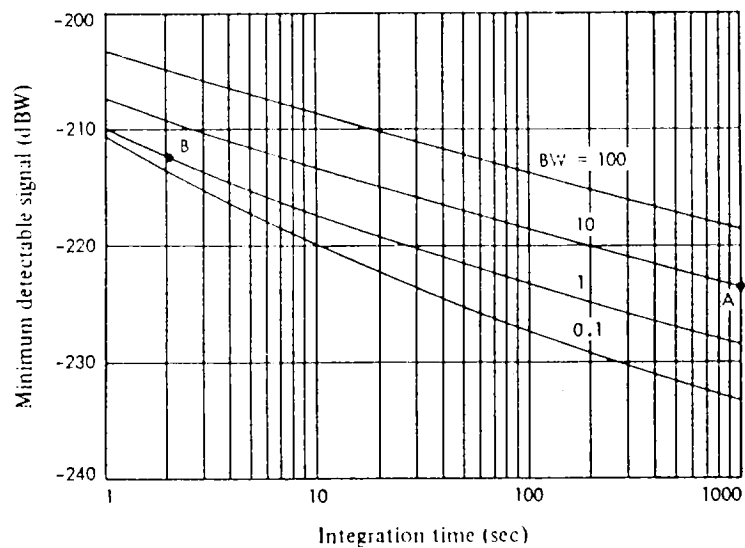* : From geostationary satellite
+ : From Voyager spacecraft at Neptune

FIGURE 2 – *Minimum detectable signal power*

30 K system noise temperature.   BW: Bandwidth (Hz)
Candidate system A: BW = 10 Hz, integration time = 2 sec
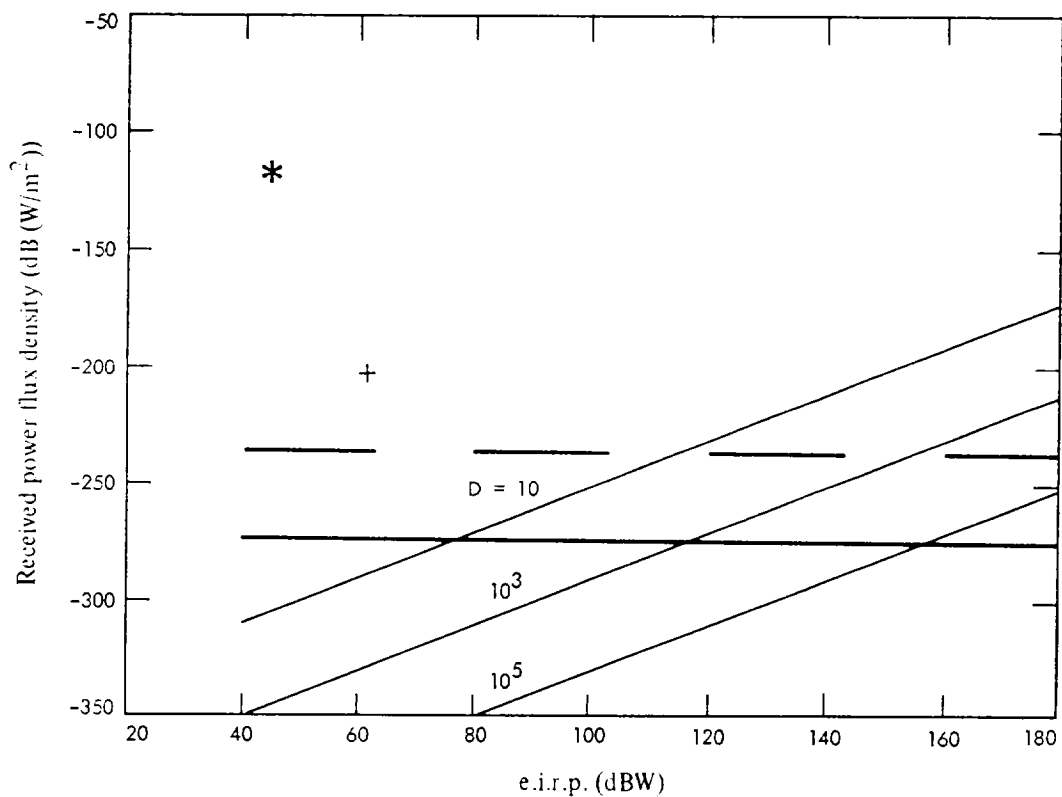   B: BW = 1 Hz, integration time = 1000 sec

FIGURE 3 — *Signal detection capability*

Sensitivity: — — — System A using 34m antenna. (see text
————— System B using 300m antenna. and Fig. 2)
D: Distance, light years. (1 light year = 9.46 x 10^{15} m)
✱ : Satellite in geostationary orbit
+ : Voyager spacecraft at Neptune

Appendix B

(Note: The text of CCIR Question 17-1/2 is given below.)

QUESTION 17-1/2

RADIOCOMMUNICATION REQUIREMENTS FOR SYSTEMS TO SEARCH FOR EXTRA-TERRESTRIAL INTELLIGENCE

(1976-1982)

The CCIR,

CONSIDERING

(a) that many scientists believe intelligent life to be common in our galaxy;

(b) that electromagnetic waves are presently the only practical means of detecting the existence of intelligent extra-terrestrial life;

(c) that it is believed to be technically possible to receive radio signals from extra-terrestrial civilizations;

(d) that, although it is not possible to know the characteristics nor to predict the time or duration of these signals in advance, it is reasonable to believe that artificial signals will be recognizable;

(e) that, while an artificial signal of extra-terrestrial origin may be transmitted at any frequency, it is technologically impractical to search the entire radio spectrum, but the band searched should be sufficiently wide to make detection of a signal reasonably probable;

(f) that technological and natural factors which are dependent on frequency determine our ability to receive weak radio signals;

(g) that the search for radio signals from extra-terrestrial civilizations will use increasingly sensitive systems which could receive harmful interference from very weak man-made signals;

(h) that it is necessary to share with other services the bands in which the search is conducted;

(i) that available technology will allow a search for these signals from the Earth, from earth orbit, and, eventually, from the Moon, and to minimize interference, certain locations on Earth and ion space may be preferred,

UNANIMOUSLY DECIDES that the following questions should be studied:

1. what are the probable characteristics of radio signals which might be broadcast by extra-terrestrial civilizations and the technical characteristics and requirements of a system to search for them;

2. what are the preferred frequency bands to be searched and the criteria from which they are determined;

3. what protection is necessary for receiving systems conducting a search for artificial radio signals of extra-terrestrial origin;

4. what criteria will make the operation of a search system feasible in shared, adjacent and harmonically related bands of other services;

5. what is the optimum search method;

6. what are the preferred locations, on Earth and in space, for a search system?

Note: See Report 700